Metamorphic temperature analysis of H chondrites: Using revised Lindsley's pyroxene thermometer

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1. Introduction
The thermal evolution models of asteroids have been proposed and discussed by many researchers to provide insight into the internal structure and thermal history of those (e.g., Wood,1979; Miyamoto et al., 1981; Yomogida and Matsui, 1984; McSween et al., 2002). As important parameters for the thermal evolution models, the highest peak temperatures, ages, and cooling rates of meteorite parent bodies are mentioned (McSween et al., 2002). The peak temperature inside the parent body has been estimated using various thermometers (Olsen and Bunch, 1984; Nakamuta and Motomura, 1999; Kessel et al., 2002; Slater-Reynolds and McSween, 2005). Pyroxene thermometer by Lindsley (1983) has been widely used because it allows us to derive temperatures from both orthopyroxene (Opx) and clinopyroxene (Cpx) in a meteorite. However, the temperatures determined from clinopyroxenes, especially for type 6 chondrites, are systematically 50˚C to 150˚C higher than those from orthopyroxenes (Nakamuta et al., 2017). The Lindsley’s pyroxene thermometer is made empirically for terrestrial rocks and therefore the kosmochlor component is not considered in the calculation. So, Nakamuta et al. (2017) proposed the revised Lindsley’s pyroxene thermometer in which the kosmochlor pyroxene component is added to evaluate the effect of the component on the thermometry. They also showed that the difference in temperature between clinopyroxene and orthopyroxene in LL chondrites using the revised thermometer was less than 20˚C.
In this study, we have attempted to estimate the metamorphic temperatures of H chondrites (type 4 to 7) using the Lindsley’s pyroxene thermometer revised by Nakamuta et al (2017). Here we report the results of the estimation.
2. Samples and method
The chondrite samples used were four types of H chondrite with different metamorphic degrees; Edmondson(b) (H4), Faucett (H5), Faith (H5), Plainview (H5), Mulga(north) (H6), Great Bend (H6) and NWA7875 (H7). Polished thin sections of the seven H chondrites were prepared and observed using transmitted and reflecting light microscopes. Then, chemical compositions of pyroxenes, olivines, and plagioclases in the seven H chondrites were analyzed by an EPMA, JEOL JXA-8530F. Beased on these results, the classification of each meteorite sample was reconfirmed, and metamorphism temperatures estimated using the revised Lindsley pyroxene thermometer.
3. Results and discussion
From results of the texture observation and chemical analysis of the chondrite sample, we reconfirmed that there is no mistake in classification of each meteorites (H4, H5, H6, H7). The temperatures for Edmondson(b) (H4), Faucett (H5), Faith (H5), Plainview (H5), Mulga(north) (H6), Great Bend (H6) and NWA7875 (H7) are 779-1236˚C (Opx-Cpx), 814-875˚C, 832-843˚C, 844-838˚C, 807-797˚C, 811-818˚C and 1183-1247˚C, respectively, using the revised Lindsley pyroxene thermometer. Most of H5 and H6 meteorite samples showed that the difference in temperature between Opx and Cpx was less than 20˚C. This result, this suggests that the revised Lindsley pyroxene thermometer by Nakamuta et al. (2017) is also effective for H chondrite. The metamorphic temperatures of the H5 type chondrite (Faucett, Faith and Plainview) and the H6 type chondrite (Mulga(north), Great Bend) are approximately 840˚C and 810˚C, respectively, while the H4 type Edmondson(b) chondrite is less than 780˚C judging from the temperature

estimated from Opx. Regarding the H7 type NWA7875 chondrite which showed the highest metamorphic temperature and lamella structure in some Cpx crystals, the H7 material that existed already in H5 and/or H6 conditions may have experienced impact metamorphism, redrawing the previous metamorphic temperature and the H5 and/or H6 conditions.

Comparing these estimated temperature data with the results of the model simulation reported by Monnereau et al. (2013), it is estimated that the H chondrite meteorite parent body had an onion shell type internal thermal structure formed when the accumulation period was short (<0.2 Myr).

Keywords: H chondrite, Lindsley pyroxene thermometer, Kosmoclor, Peak temperature, Onion-shell model